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USING GIS TO ANALYSE LAND USE CHANGE IN BISTRIȚA SUBCARPATHIAN VALLEY

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Key words: land use, GIS, Bistrita Subcarpathian Valley.

Abstract. The goal of the study is to further develop an appropriate technique for quantifying and analysing the long-term land use changes using GIS. This method may contribute to a better understanding of the landscape dynamics over a period of more than 200 years. The study was carried out in Bistrita Subcarpathian Valley, which has an intensively utilized agricultural landscape. The cadastral maps and the present-day orthophotograph map of the Bistrita Subcarpathian Valley were used as mainly data resources. They have been digitized, interpreted and analysed in the GIS environment. The knowledge that is acquired can be applied in planning processes in order to provide relevant landscape management in the future.

Introduction

Changes in land use and land cover are some of the far-reaching effects of human activities on modern landscapes (Bender et al., 2005). Land cover (LC) and land use (LU) are two key elements describing the terrestrial environment in relation to both natural processes and human activities. Land cover refers to objects located on the planet surface which are of either natural or anthropogenic origin (Jansen & di Gregorio, 2002). In contrast, LU refers to objects that represent human activities that result in the production of goods and services for society. (Mendoza et al., 2011)

Investigating landscape structure and its change is a prerequisite to the study of ecosystem functions and processes, sustainable resource management, and effective land use planning. However, such an investigation has been traditionally limited due to the difficulty in acquiring and processing high-resolution spatial data. (Matsushita B., 2006)

With the advances in remote sensing and geographic information system (GIS) techniques, characterizing a landscape and quantifying its structural change has become possible in recent decades (Forman and Godron, 1986, cited by Matsushita B., 2006).

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1.Study area

Bistrita Subcarpathian Valley is a predominantly rural region which „goes from Piatra Neamt to Racova (...) from Racova, Bistrita entering the Moldavian Plateau”.(Donisă, 1968) In this valley sector are found three urban centers that show a rather large influence on surrounding villages. The large extension of the terraces and pedogeographic favorable conditions led to a significant agricultural use. Furthermore, the proximity of quality water sources allowed the establishment of large industrial areas giving a distinct mark the landscape area.

This subcarpathian groove is largely ovellapped over Cracau-Bistrita Depression, which is enclose by isolated hills to the north, south and east, and separated into two sections: the northern, named Cracau depression, and the southern, called Bistrita-Roznov depression.

The orientation on the NV direction of the valley on the Bistrita-Roznov depression doesn't influence particularly this unit's morphostructure.

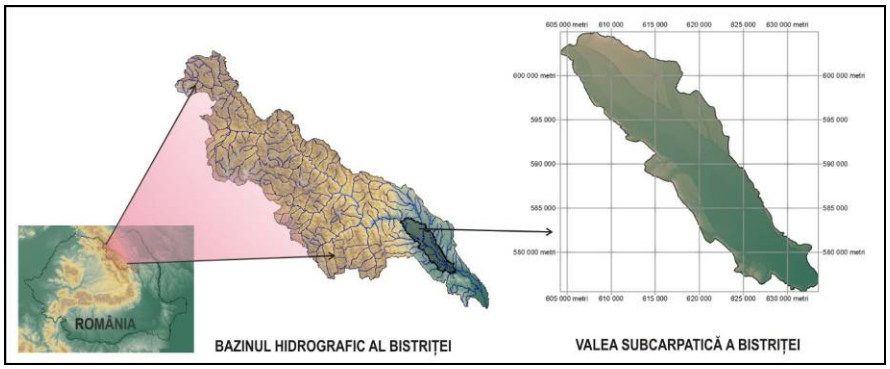

Fig. 1 – Geographical location of Bistrita Subcaphatian Valley

The proper delineation of the area was a very difficult approach correctly expressed by Donisă (1968): "If the definition of a valley in theory does not involve special difficulties when it comes to precisely delineate on the field the extension of valleys, in some cases we can experience serious difficulties. This is even more as there are larger valleys, whose slopes were fragmented and changed by the action of tributaries and slope processes. "

To establish the limits of the territory we used different materials, a key role representing the papers which analysed the area under study from a physico-geopraphical point of view. They delimit the subcarpathian sector of Bistrita Valley starting out of the typical flysch mountain, located in Piatra Neamt, until Racova,

on whose territory is the fault which delimits the Pericarpathian molass by the Moldavian Platform.

For greater accuracy in determining the limits we have considered both geomorphologic and geological criteria. We used the following cartographic matherials: the detailed digital elevation model made after extracting the altimetric information on 1:5.000 scale topographic plans, the geomorphological map of the terraces made by Donisă in 1968, and the geological map taken from R.S.R. Atlas, 1:200.000 scale, Piatra Neamț sheet.

For the study to be complete, in some cases we will have to overcome the limits of the valley and perform research on a much larger territory. Thus, in order to clarify some socio-economical aspects, but mainly to get an overview of the processes and phenomena from Bistria Subcarpathian Valley, we will utilise administrative boudaries of localities for the area under study. The only locality included only parially in the cartographic analysis is represented by Piatra oimului, because part the administrative territory goes out of our area of interest, by entering pretty much in the mountains.

2.Matherials and methods

Data acquisition .The analysis was achieved through GIS methods using the following cartographic matherials: 1:20.000 scale Austrian maps made in 1788/1790, obtained from the Romanian Academy Library, Bucharest, old maps from the Romanian Atlas at 1:50.000 scale made in 1896, military maps at 1:20.000 scale(1912-1957), 1:5.000 topographic plans, 1975/1976 edition, 1:10.000 cadastral plans, 1986 edition, 1:25.000 topographic maps(1984), and 2005/2006 ortophotomaps obtained from ANCPI.

Due to the use of cartographic matherials from different periods and at different scales, the analysis of environmental components was made from two perspectives: qualitative and quantitative. The analysis of cartographic documents was realised both from a statical point of view, in which the elements were analyzed as a whole in each map and dynamic, which tracked the evolution of each component.

*Analysis.*The qualitative analysis was applied to the use of all strings of maps at close scales available, from the austrian map made in 1788/1790 to the aerial imagery from current period. The goal of utilizing these maps is to capture certain patterns of evolution, and to explain the causes of these phenomena. Although we experienced some geometric mapping errors, different projection systems, some of the maps being non-unitary, and made for specific purposes, rather large scales that are made, all cartographic materials allow us to extract some common features. In order to capture the changes of the landscape elements in the Bistrita subcarpathian valley based on analysing the cartographic documents is

necesary an inventory of all elements that appear on all maps, followed by a comparative analysis of the same element on each map. From their analysis we can highlight the areas that remain constant, but especially those who have a pronounced dynamics.

The quantitative analysis is based on geostatistical methods to quantify changes in land use categories. This type of analysis was made after processing the latest cartographic documents at detailed scales(topographical plans at 1:5.000 scale, cadastral plans 1:10.000 scale and ortophotomaps at 1:5.000 scale), that allow us to quantify precisely and as close to reality of each element's surfaces and, also a relevant diachronic analysis. We emphasized for the representative categories the surface expanding and tightening, and also the categories in which expense these changes were made. Applying this method shows satisfactory results and, by their correlation with different events and natural phenomena, socio-economical, historical, political or others we can highlight the causes that led to these changes.

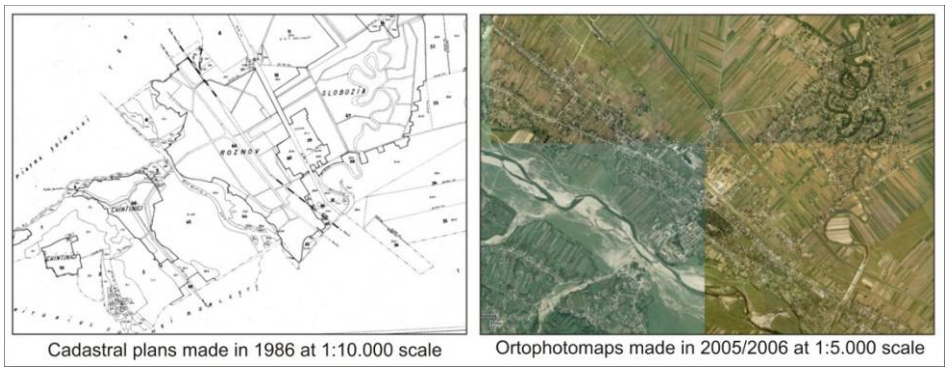

Fig. 2 – Main cartographic matherials used

*Data processing.*In order to be input into GIS environment, the data has to be passed into electonic form. Thus, we transformed the data from analog to digital by scanning operation. Then they are imported into GIS software used, and georeferenced by the coordinates displayed on maps or by correspondence method. The ground control points for georeferencing are map elements that can be recognized in both data records, and that supposedly cannot change their position over a long period of time, leaving their intersections relatively intact over a long period of time. All matherials were re-georeferenced and brought in Stereo 70 projection system so as to have a cartographic base reunited at the end.

Necessary spatial data were extracted both by direct digitization, through ON SCREEN method, or by semiautomatic vectorization methods, depending on the quality of the catographic documents. We obtained in the end a set of spatial data in a easy to process and analyze format.

All these processes and the resulted maps were made using the professional softwares TNT Mips Microimages 7.2 and ArcGIS 10.1.

3.Results and discussions

Visual analysis of multi-temporal cartographic documents illustrated a high degree of land use change in the youngest period under investigation, which covered the period from 1788 to 1986(Austrian maps, military survey old maps). Within this period we can highlight at the beginning a significant loss of the woodland, especially in favor of arable and built-up area. The main cause of this phenomena is the demographical factor, the continuous increasing of inhabitants number with their implicit needs imposed a territorial expansion of the built-up area and of course, the occurrence of new arable lands.

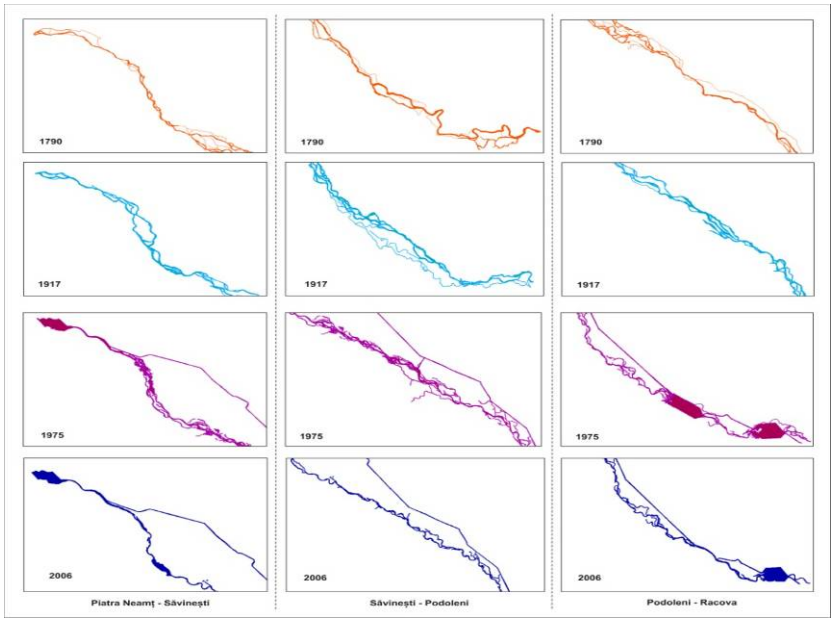

Fig. 3 – Bistrița riverbed morphdynamics of the subcarpathian sector Piatra Neam - Racova

By the middle of last century, the land use of the study area was closely related to the river Bistrita, which acted as a real communication route very important for the economic life of the entire subcarpathian valley. The river had great variations, so the inerent floods had sometimes a devastating character. These floods often changed Bistrita river bed configuration. For these reasons, Bistrita represented in the past a restrictive factor in terms of built-up area expansion.

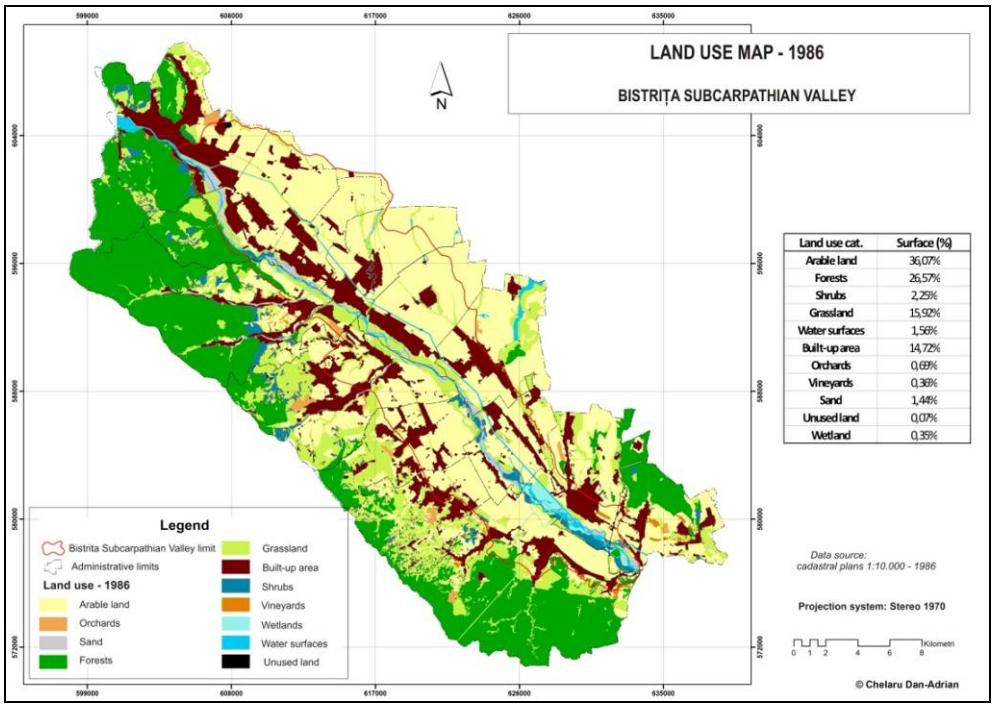

Fig. 4 – Distribution of land use categories: 1986

After the regularization works of the Bistrita river in 1960 and putting into service of the entire hydropower system, the economic role and the appearance of Bistrita changed. The rafts disappeared, appeared hydropower as a source of clean energy, water flow variations are much lower than the past, and appeared new lakes and dams that completely changed the aspect of Bistrita river bed. These changes have allowed the expansion of houses in old floodplains and especially the appearance of new arable land in the proximity of the river.

Availability of cartographic documents from recent times at large scales has permited us to realize two land use maps on which can be done geostatistical analysis with a high accuracy. Thus, the land use map made on the basis of

cadastral plans from 1986 (fig. 4) showed that the study area of Bistrita Subcarpathian Valley consisted mainly in arable land(36,07%), forests(26,57%), grassland(15,92%) and built-up area(14,72%).

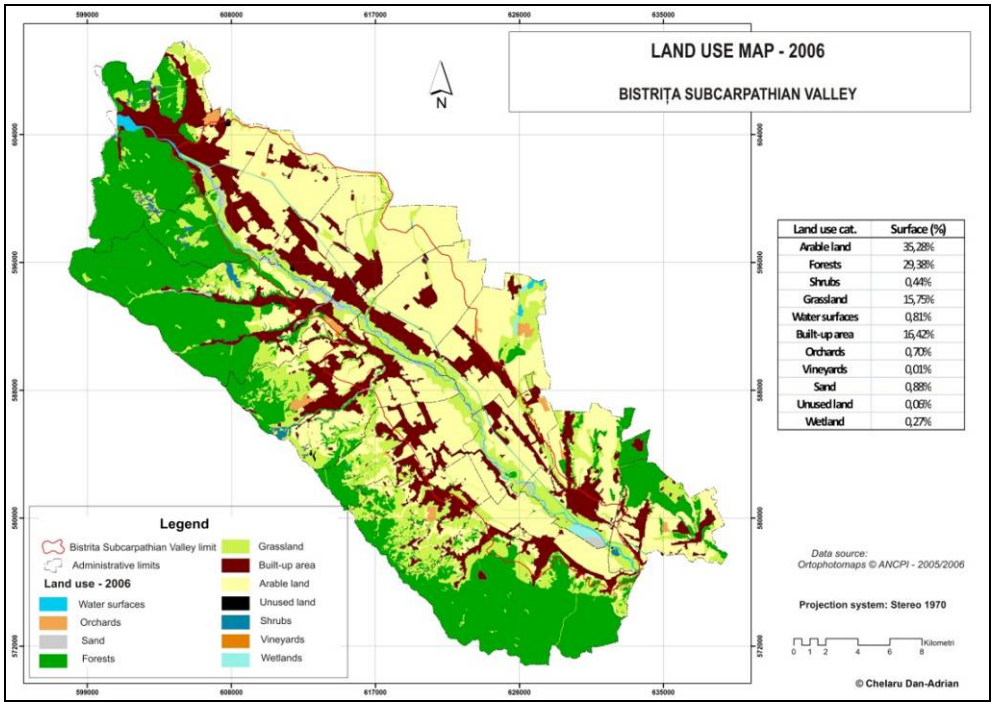

Fig. 5 - Distribution of land use categories: 2006

Regarding the present day land use map made by ortophotomaps (fig. 5), can be seen some changes in the percentages held by each category. Thus, arable land is still the predominant type of land use with 35,28% from total area, but with a less percentage than the first period, followed by forests(29,38%) and grassland(15,75%), that have almost the same proportion and built-up area, which shows the highest rate of growth: 16,42%.

Use of the serial database of cadastral maps and land registers offers several advantages concerning availability, accuracy, and information contents. The most important one is increased accuracy regarding content and geometry, which facilitates the detection and capture of data relevant to natural resource management. (Bender et al., 2005)

Bistrita subcarpathian valley is a predominantly rural region, in which the main occupation of the inhabitants were agriculture. For this reason, the most

extensive land use category is represented by arable land. Nevertheless, the resulted data(tab. 1) shows that arable land areas has decreased from 24.678 to 24.192 ha. The analysis shows that the changes were made at the expense of grassland(1408,32 ha), built-up area(1125,54 ha) and forests(248,76 ha). These changes can be attributed to 3 main stages, depending on the evolution of political and socio-economic factors:

Characterized by a certain economic inefficiency hidden by inaccurate statistical reporting, the *Communist system* promoted an agriculture developed on large areas. *After 1990*, the centralized system of land management was abolished and most of the equipment lost functionality. The average farm size reduced to approximately 2.5 hectares. (Patroescu et al., 2011) Therefore, the peasants practiced a subsistence agriculture, and the parcels fragmentation level was even bigger than the interwar period.

Land use category	Period under study	Surface 1986 (ha)	Areas affected by changes for the following categories of use (ha)										Surface 2006 (ha)
			Arable land	Forests	Shrubs	Grassland	Water surfaces	Built-up area	Orchards	Vineyards	Sands	Unused land	Wetlands	
Arable land	1986 – 2006	24677,93	-	248,76	7,72	1408,32	11,54	1125,54	28,78	0,39	5,07	2,71	1,29	24191,81
Forests	1986 – 2006	18179,52	29,08	-	92,21	456,47	3,38	51,76	0,13	0	6,42	0	0	20147,37
Shrubs	1986 – 2006	1537,23	98,72	504,58	-	647,73	18,52	36,80	3,78	0	77,29	1,09	34,05	302,33
Grassland	1986 – 2006	10893,33	1585,94	1578,12	77,45	-	61,96	394,86	125,90	0,42	121,05	6,43	21,76	10801,09
Water surfaces	1986 – 2006	1064,59	61,29	4,55	0	360,02	-	55,35	1,61	0	136,33	0,09	83,50	554,24
Built-up area	1986 – 2006	10068,72	355,29	87,08	7,57	143,41	3,06	-	9,26	0	15,52	0,40	0,02	11258,93
Orchards	1986 – 2006	472,22	44,54	53,10	0	42,46	0	32,96	-	0	0	0	0	476,76
Vineyards	1986 – 2006	248,96	133,34	27,09	0,34	64,90	0	14,50	8,70	-	0,10	0	0	6,53
Sands	1986 – 2006	987,21	14,47	29,73	1,65	505,54	85,46	94,16	0	0	-	13,24	20,39	601,09
Unused land	1986 – 2006	51,24	6,48	4,07	0	20,61	0,39	2,61	0	0	0	-	0	41,13
Wetlands	1986 – 2006	241,98	4,76	0	0,35	183,81	12,92	0	0	0	17,12	0,09	-	183,93

Tab. 1 – Categories of land use change

Also, the changes in the use of agriculture surfaces had visible effect on the landscape. There was a period when the crop surfaces diminished because of the land abandoning. The main causes were the maintenance`s high prices, poor infrastructure, the lack of the production way, the relatively small production, the aged population and the uninterested new owners. Same thing happened to the vineyards and the orchard, that reduced their productivity because of the precarious maintenance. Therefore, these surfaces had been grubbed and arable lands, pastures and meadows took place. (Chelaru et al., 2011)

Since 1995 there is a tendency of farmers association, who wanted to practice intensive agriculture, possible only on large lands. Because of an old agricultural infrastructure and the lack of financial resources, few farmers were able to follow this model. *Starting 2005*, subsidies were been given (aproximately 60% of the acquisition cost) in order to get agriculture equipment, that helped to constitute an important agriculture infrastructure. The most advantageous agriculture organization form is the agriculture association with property rights. This model of agricultural organization complies with the requirements imposed by the European Union for the adhesion process in agriculture sector. (Chelaru et al., 2011)

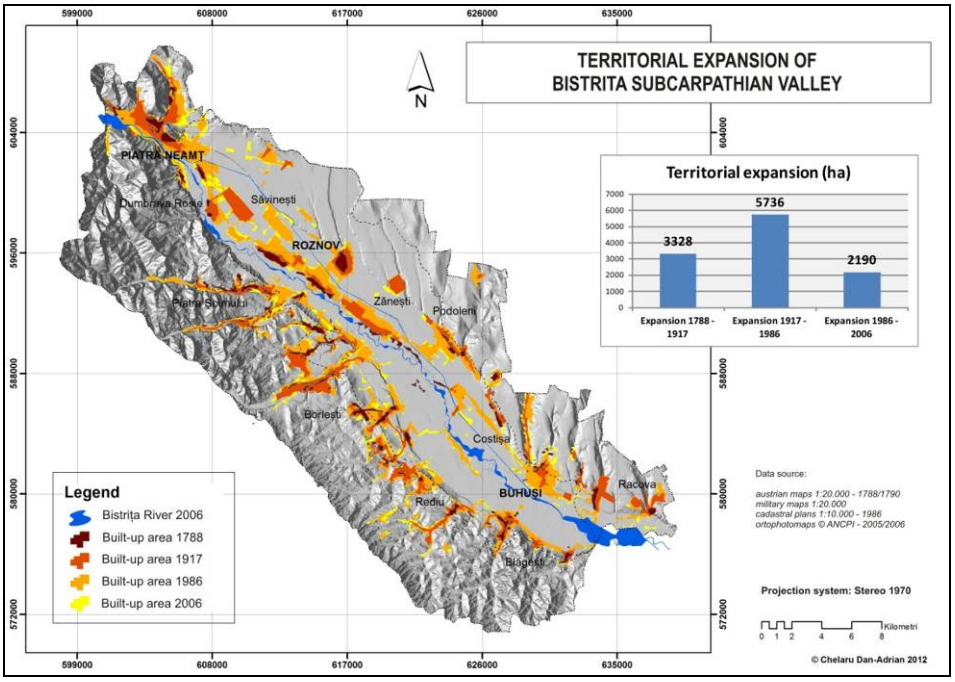

Fig. 6 – Territorial expansion of Bistrița Subcarpathian Valley

Regarding forests, we can say that in the present the situation looks hopeful. In the study area woodlands has increased slightly unlike other neighboring regions where deforestation phenomenon has grown. Land use categories that have been changed in this respect are arable land(248,76 ha), grassland(1578,12 ha), and shrubs(504,58 ha). Note that the old shrubs subsequently became woodlands.

Grassland represents the land use category whose surface remained relatively constant in this period, yet the internal configuration suffered substantial changes. Thus, during the time, pastures have replaced some plots of arable land, 1408 ha precisely, the causes being mentioned above. Also, grassland occured in areas affected by deforestation, wetlands (ponds that were drained), or even at the expense of orchards and vieyards, whose areas declined dramatically nowadays.

Over time, the most obvious and interesting changes occurring in land use are represented by the expansion of the built-up area. On the analysis of the map which shows the extended areas of the city built in 1986-2006 period was observed that these changes occurred generally at the expense of arable land(1125,54 ha), and secondary to the grassland(395 ha).

Overall, the total area in this period is extended by 2190 ha(fig. 6), and this is accomplished mainly due to demographic factors. The causes can be found both in the period before the fall of communism and after. Thus, if prior to 1990 the territorial expansion was largely done through the rapid process of industrialization, being developed some new industrial sites, in the next period this expansion was due to the population desire of increasing the comfort indicators.

Similar to the rest of the country, our study area has experienced an unprecedented real estate development. The period after 1990 was a good and quick oportunity for some people to get rich. They illegaly bought agricultural plots, which were converted by legal means to buliding land. Of course these changes have nothing in common with sustainable development principles.

Conclusions

The study indicates that the use of GIS techniques for the analysis and evaluation of land use change proves to be adequate, having the advantage of allowing us to monitor long time intervals, depending on the available cartographic documents.

Concerning our analysis, some remarkable changes have been recorded, not only over the entire investigated period, but also between the individual time horizons, where the different dynamics of the individual land cover types is shown most clearly. In addition to the information on absolute changes, the information on the rate of change is also of very high importance, as the rate of change differs according to the time horizons. (Skalos et al., 2010)

Results are important in planning processes and territorial administration. They can be used to manage and monitor land resources, to assess the impact of human activities on the environment, and also for certain land use category expansion necessities. This study allows us to formulate some conclusions, both in general, about land use, and individual on every type of land use.

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